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ATOMIC WEAPONS RESEARCH ESTABLISHMENT

REPORT No. T 6/59

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OPERATION ANTLER

Target Response Group
(Group Leader Plans: E. R. Drake Seager)
(Group Leader Operations: Lt. Col. E. T. Wray, REME)

The Effects of Blast on Dummies and Scout Cars

Maj. A. R. F. Martin, RA

A.W.R.E.,
Aldermaston, Berks.

August, 1959

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Summary

See page 2.

Summary

30 Dummy Men in the open and 4 in Daimler Scout Cars were exposed to Round 2.

Although all items were set out primarily to test target response instrumentation, useful information confirming and extending data from Operation Buffalo was obtained from the dummies. Because Round 2 was of lower yield than had been assumed in initial target response planning, little new information was obtained from the Scout Cars.

On Round 3, pairs of dummies were exposed in each of 8 Champ Vehicles and 6 further dummies exposed in the open as controls at the 3 nearest in positions. Because of the presence of a precursor, all these dummies suffered severe damage.

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1. Introduction

Target response in Operation Antler was planned as a sequel to similar trials in Operation Buffalo. In the earlier trials a considerable number of dummy men and a variety of military equipment had been exposed to the effects of an atomic weapon, and various means of instrumentation had been used [1][2]. Accelerometers had been fitted to dummies and equipment, and attempts had been made to photograph the movements of the targets under the impact of the blast wave. These achieved only partial success, so new techniques were devised, the testing of which was a first priority for the targets exposed on Operation Antler. It was nevertheless hoped to add to the target response data obtained on Operation Buffalo.

The target layout for Operation Antler was based on the assumption that the weapon to be used would be of similar size to that of Operation Buffalo, Round 1, but shortly before the trial it was learned that the yield was to be considerably less. To compensate for this fully, it would have been necessary to move the layout forward, by constructing additional positions nearer Ground Zero and enlarging the more forward positions already constructed. The whole cable network for instrumentation would also have required radical alteration. At such a late stage this course would have been impracticable, and all that could be done was to insert two positions for dummies in front of the original target layout. Prone dummies only were placed at these positions, so that no engineering work, except a survey,

was required. It was not found possible to fit them with accelerometers in the time available.

2. Object

To obtain information on the effect of blast from a nuclear weapon upon Dummy Men and Daimler Scout Cars.

3. Method

3.1 Round 2

30 dummies were exposed in the open at various ranges in different postures - standing, crouching, or prone - each posture being repeated facing and sideways-on to Ground Zero. The standing and crouching dummies were supported on a frame-work of tubular scaffolding (see Figures 8 and 10). One dummy was standing in a trench (see Figure 23).

The dummy men had been developed by RAE, Farnborough, to represent standard airman. They weighed 175 lb (12½ stone) and were 6 ft 1 in. tall. The distribution of weight in the limbs corresponded to that expected in an average man of these dimensions. They were dressed in white overalls, and steel helmets were worn by those prone and crouching. The straps were behind the head in each case, to allow free movement of the helmets when the blast wave arrived. Although this method of securing the helmet has been used from time to time, it is not the current practice in the Services. A study of the hazard from the helmets as missiles was made and is reported elsewhere. It might be mentioned here that on Operation Buffalo steel helmets worn with the strap under the chin were found to present serious hazard to the wearer when exposed to blast [1].

Daimler Scout Cars were exposed at 4 positions sideways-on to Ground Zero, each containing a dummy in the driver's seat. All were in sound mechanical condition and had been driven onto the site. Radio sets were not fitted.

3.2 Round 3

There was originally no intention of deploying targets for Round 3, but shortly before the trial, the Director of AWRE decided to expose eight old ¼ ton 4 x 4 Champs to investigate certain blast characteristics of the weapon. Advantage was taken of this to put a pair of

dummies in each of these vehicles. Furthermore in order to obtain comparable data on dummies at similar pressure conditions outside the vehicles, pairs of prone dummies, consisting of one facing and one sideways to the blast, were placed at the three nearest-in positions. It was considered that the remaining Champ positions would be covered by information from prone dummies exposed to Round 2.

3.3 Measurements and Photography

The displacement of all targets was measured using a steel tape. The datum for the original position of a target was indicated by a 4 in. nail painted white, and driven into the ground with about $\frac{3}{4}$ in. protruding. In the case of the dummies the displacement recorded was that of the navel or front centre of the belly. Displacement of the helmets was also measured, to investigate their significance as missiles.

Photographs were taken of each dummy position before firing and of each individual dummy after firing, showing its final posture after the blast. Similarly photographs of the Scout Cars were taken both before and after firing. A representative selection of the photographs is included in this report (see Figures 2 to 24). A complete set is held by GS(W)11, The War Office, to whom application to view should be made.

3.4 Assessment of Damage to the Joints of Dummies

The leg and arm joints of the dummies varied considerably in stiffness. Although it was not found possible to adjust all joints to a constant figure a qualitative assessment was made both before and after firing of the actual stiffness of the limbs. Each joint was judged as being loose, medium or stiff.

4. Results

4.1 Detailed Results

Details of the damage suffered by each dummy in the open, the Champs and the Scout Cars are given in Appendices A, B and C respectively.

Details of damage to the Scout Cars are given in Appendix C.

Appendix D gives the basic blast and thermal data for Operation Antler, Rounds 2 and 3.

On Round 2, one dummy was standing in a trench which was at right angles to the radius from Ground Zero at Site P17 (2390 ft). The dummy was facing Ground Zero with the rim of its steel helmet about level with the lip of the trench (see Figure 23). This dummy was exposed primarily to test a camera installation, but after firing it was observed that it had not moved and had apparently suffered no damage (see Figure 24).

4.2 Tabulated Results

Table 1 gives a summary of the displacement of all dummies in the open on Round 2. Table 2 is a similar summary of the displacement of the dummies in the open and in the Champ vehicles on Round 3. Table 3 shows the number of changes in joint stiffness found in the dummies in the open after exposure to Round 2.

TABLE 1

Displacement of Dummies - Round 2 - Tower Burst

Target No.	Range from Ground Zero, ft	Peak Static Overpressure, p.s.i.	Peak Dynamic Pressure (Calculated), p.s.i.	Duration of Positive Phase, sec	Displacement, ft											
					Prone				Crouching				Standing			
					Facing		Sideways		Facing		Sideways		Facing		Sideways	
					Facing	Sideways	Facing	Sideways	Facing	Sideways	Facing	Sideways	Facing	Sideways		
P18	1460	15.1	5.0	0.38	6	11										
P19	1590	13.1	3.7	0.40	6	28										
P10	1840	9.8	2.2	0.44	1/4	14										
P16	2000	8.3	1.6	0.46	1/4	4(a)										
P12	2200	7.0	1.1	0.48	1/4	4			4	7						
P13	2390	6.1	0.9	0.50	Nil	2			7	8			16		8(b)	
P14	2650	5.1	0.6	0.53	Nil	1			1/4(c)	5			15		9(d)	
P15	3110	4.0	0.4	0.57					Nil	3			11		6	
P11	3900	2.8	0.2	0.63					Nil	Nil			6		5	

NOTES: 1. Displacement may have been reduced by the factors noted below:-

- (a) Dummy caught in wire mesh of sealed surface;
- (b) Dummy's head hit junction box;
- (c) Tunic caught on scaffold pole;
- (d) Dummy's feet caught in cable.

2. Peak Static Overpressure and Duration of Positive Phase were obtained from graphs plotted from data obtained in the Instrument Lane, which was on a different axis to the Target Response Lane.

TABLE 2

Displacement of Dummies - Round 3 - Airburst

Target No.	Range from Ground Zero, ft	Duration of Positive Phase, sec	Peak Dynamic Pressure, p.s.i.	Displacement of Dummies, ft			
				Dummy Position			
				Prone		In Champ	
				Facing	Sideways	Passenger	Driver
501	1860	0.61	12.0	5	67	87R	97
502	2110	0.65	7.9	70	280	115R	115
503	2380	0.68	5.1	79	170	88	66R
503S	2380	0.68	5.1			515	534
504	2630	0.71	3.6			28R	28R
505S	2825	0.73	2.9			65	74
506	2920	0.75	2.4			30R	30R
507	3110	0.76	2.0			9R	9R

- NOTES:
1. The suffix 'S' to the target number shows the car was at right angles to a radius from Ground Zero. In other cases the cars were on a line about 8° to the right of a radius to Ground Zero.
 2. The suffix 'R' to displacements of the dummies in Champs indicates that it remained in vehicle.

TABLE 3

Dummies in the Open - Round 2 - Changes in the Stiffness of Joints

	Posture						Total for All Dummies
	Prone		Crouching		Standing		
	Facing	Sideways	Facing	Sideways	Facing	Sideways	
Number of Dummies Exposed	7	7	5	5	4	4	
	Joint Changes						
Knee	2	3	3	1	1	1	11
Hip	6	7	1	4	3	3	24
Elbow	2	Nil	Nil	Nil	3	Nil	5
Shoulders	4	4	3	3	3	1	18
Total for All Joints	14	14	7	8	10	5	58

4.3 Scout Cars

Because the yield of Round 2 was designed to be lower than had been assumed in the initial planning, the Daimler Scout Cars were not subjected to a large enough blast pressure for them to be greatly affected. Only the leading car at 1730 ft from Ground Zero had moved at all significantly. This car turned onto its side, spilling its dummy driver onto the ground, but did not undergo any actual translation. All the cars could be driven away after exposure. In the other cars at 2200, 2530 and 2650 ft movement was only a few inches and the dummy drivers were not affected. Details are shown in Appendix C and Figures 20, 21 and 22.

5. Discussion

5.1 Effects of Blast on Dummies

Men exposed at the dummy positions would have suffered severe flash burns on exposed skin, those closer than 2200 ft to Ground Zero of Round 2, and all on Round 3, would have received a supra-lethal radiation dose. Nevertheless the blast effects seen in this trial should not be considered solely as a possible additional cause of death to men already dead. Similar conditions can be expected in the outer fringes of the area affected by a Megaton weapon, beyond the range of serious danger from nuclear radiation. These blast conditions can also occur where men are otherwise protected from heat and nuclear radiation.

The displacements of dummies exposed to Rounds 2 and 3 are given in Tables 1 and 2. As would be expected Table 1 shows that, broadly speaking, displacement decreases with increasing distance from Ground Zero, and with decreasing area presented to the blast wave by the posture of the dummy. These areas are approximately as follows:-

<u>Posture</u>	<u>Area Presented, ft²</u>
Prone Facing	1½
Prone Sideways	5
Crouching Facing	4
Crouching Sideways	5
Standing Facing	10
Standing Sideways	5

If Figure 1 the displacements of the dummies have been plotted against a quantity - the product of the peak

dynamic pressure, the positive phase direction and the presented area, which is proportional to the impulse received by the dummies. The quantity is not the impulse itself, since it takes no account of the hydrostatic pressure rise of very short duration, the drag coefficient of the dummies, or the decay of the dynamic pressure to zero at the end of the positive phase. The regression line with 95% confidence limits obtained from similar results from Operation Buffalo has also been drawn on the Figure.

Agreement between Operation Antler and Operation Buffalo results is fair, bearing in mind that three weapons of different yields and heights of burst are involved. Too close an agreement between dummies in different postures is also not to be expected. A prone dummy if sideways to the blast will tend to roll, whereas if facing Ground Zero it cannot do so until other movement has taken place. A dummy prone facing will have considerably greater frictional resistance to motion. However, inspection of Figure 1 fails to show displacements of dummies prone sideways to be significantly greater than those prone facing, considering the greater area presented by the former.

A standing dummy offers little frictional resistance to motion, and moreover does not require its centre of gravity to be lifted before becoming airborne. It would therefore be expected to suffer relatively greater displacements than prone and crouching dummies of similar presented area. This does appear to be borne out in Figure 1 where standing dummies show consistently higher displacements.

There are other unpredictable factors which affect the motion of dummies. During flight the trunk may turn and limbs wave in various directions, thereby altering the area presented to the accelerating blast wind. When the dummy finally lands it may do so in such a way that it rolls, or it may not.

With regard to changes in the stiffness of joints (see Table 3), it seems that prone dummies suffered most although they moved least. Hips and shoulders suffered more than elbows and knees.

The results of Round 3 are of considerable interest as a precursor was present. Under these conditions the peak static overpressure is less than would be expected from a normal blast wave, but the dynamic pressure is probably unaffected and the duration of the positive phase greatly

increased. The resulting translational impulse is thus considerably greater. Displacements of the prone dummies exposed to Round 3, although substantial, were not greater than would have been expected from these considerations, as can be seen in Figure 1. The two unexpectedly low values were obtained from dummies at Target 501, sited 10 ft behind a very small ridge 9 in. high, and illustrates the protection from blast which can be gained from quite small features.

Apart from large displacements suffered by targets in the precursor area, which can be explained by the increased duration of the positive phase, very much greater damage occurred than values of the pressure would lead one to expect. Thus limbs were broken off, the foam rubber "flesh" badly torn, and the dummies in some cases completely broken up.

Of the various cine films taken of the dummy positions, one is of considerable interest. This shows the Standing Facing Dummy of Target P13 of Round 2 at 2390 ft from Ground Zero. The dummy can be seen being struck by the blast wave, bending in about the middle away from the blast and the tunic torn from the waist leaving fragments attached to the neck and feet. Finally, the whole body was carried away by the blast wind. In later frames the reverse pressure phase is indicated by a reversal of the direction of the dust cloud, and a swing back of all the instrumentation cables towards Ground Zero from their initial displacement during the positive phase.

5.2 Steel Helmets

The helmets fitted to the dummies travelled considerable distances (see Appendices A and B). Their significance as missiles on the battlefield is discussed elsewhere.

The displacements of the helmets were frequently over 100 ft, implying that a very substantial force would be applied to the neck of a soldier wearing a steel helmet with the strap under the chin. The critical distance from Round 2 for neck injury probably lies between 3110 ft, where at a peak static overpressure of 4 p.s.i. a helmet was flung 66 ft and 3900 ft where the distance was only 15 ft the peak static overpressure being 2.8 p.s.i. Both helmets were on crouching dummies sideways to the blast. It seems fairly safe to say that for overpressures greater than 4 p.s.i. injury must be expected.

With dummies facing the blast, either prone or crouching, the helmet often remained on the head throughout the positive phase.

5.3 Scout Cars

Because the yield of the weapon actually fired was much lower than had been assumed in the initial target response planning, only minor damage was done to the Scout Cars and so little new data were obtained. However, the critical conditions for overturning a Daimler Scout Car sideways on to the blast were bracketted, the car at 1730 ft from Ground Zero of Round 2 was turned over while the one at 2360 ft was not.

The blast characteristics at these two points are as follows:-

Range, ft	Peak Static Overpressure, p.s.i.	Dynamic Pressure, p.s.i.	Duration of Positive Phase, sec
1730	11.0	2.8	0.42
2200	7.0	1.1	0.48

6. Conclusions

(a) The information obtained on the displacement of dummies by blast confirms and amplifies that obtained from Operation Buffalo.

(b) Damage to dummies was more severe in the area affected by the precursor blast wave of the balloon burst weapon of about 25 kilotons total yield, than would have been expected from results at similar peak static overpressures obtained from the tower burst weapon of about 5 kilotons total yield where no precursor was present. It is important to remember that precursor conditions only occur when the blast is likely to be very severe in any case.

(c) The conclusion reached after Operation Buffalo, that the best position for a man caught in the open when struck by a blast wave is prone and facing the blast [1], was confirmed.

(d) The wearing of a steel helmet with the strap under the chin is likely to lead to neck injury if the wearer is struck by a blast wave of peak static overpressure greater than 4 p.s.i.

(e) The critical blast wave conditions for overturning a Daimler Scout Car when it is placed sideways-on to the Ground Zero of a tower burst weapon of about 5 kilotons total yield are probably between 7 and 12 p.s.i. peak static overpressure.

~~_____~~

Target No.	Range, ft	Dummy		Axial, ft	Laterally, ft	Observations	Displacement of Helmet, ft
		Position	Orientation				
P18	1460	Prone	Facing	6	-	On face sideways to Ground Zero. Left arm doubled back. Overall in shreds and charred. Left elbow, right shoulder and right hip loosened	On ground just in front of head
P19	1590	Prone	Facing	5	2	Lying face down, hands to sides. Overall fattered. Right elbow and left hip stiffer. Right hip loosened	6%
P19	1590	Prone	Sideways Right Side	11	3	On back. Right shoulder buried in ground. Overall badly torn and charred down right side. Right shoulder, left knee stiffer. Right hip loosened	111. Found near p19P
P19	1590	Prone	Facing	5	2	Lying face down, hands to sides. Overall fattered. Right elbow and left hip stiffer. Right hip loosened	6%
P19	1590	Prone	Sideways Right Side	28	-	On right side. Left leg doubled under. Overall nearly stripped off, badly torn. Ground Zero. Left shoulder stiffer. Right shoulder, right hip and left knee loosened	169%
P20	1840	Prone	Facing	8	-	On face. Left arm with hand to side. Right sleeve of overall torn. Left knee loosened, right hip stiffer	On ground just in front of head
P20	1840	Prone	Sideways Left Side	14	-	Lying on back. Feet to Ground Zero. Tunic left side torn, originally facing Ground Zero. Left hip loosened	106%
P16	2000	Prone	Facing	8	-	Sealed surface, of wire mesh over tarpaulin, at this position. Hands to sides. No change found in joints	Still on head
P16	2000	Prone	Sideways Right Side	2	-	Caught in coil of mesh disturbed by blast, which probably impeded motion. Lying on back. Left and right hips loosened	72
P12	2200	Crouching	Facing	4	2%	Lying on right side. Right arm bent under and back. Right sleeve torn. Right shoulder and left knee loosened	7%
P12	2200	Crouching	Sideways	7	-	Lying on left side. Overall torn left sleeve and trouser. Right leg doubled back. Left shoulder, left hip and right hip loosened	Helmet not found
P12	2200	Prone	Facing	8	1/3 at head	Hands to side, lying on face. Left shoulder, left knee and right hip loosened	19%
P12	2200	Prone	Sideways Left Side	4%	-	Lying on back, legs apart. Left sleeve torn. Left and right hips loosened	50
P13	2390	Standing	Facing	16%	-	Lying on right side, left arm bent back torn and charred. Left and right elbow, left knee loosened. Right hip stiffer	Not worn

Results of Exposing Dummies in the Open

A1. Round 2

APPENDIX A

APPENDIX A (Cont.)

Target No.	Range, ft	Dummy		Displacement		Observations	Displacement of Helmet, ft
		Position	Orientation	Axial, ft	Laterally, ft		
P13 (cont.)		Standing	Sideways Left Side On	8½	3	Lying on left side, left arm bent back under. Head against junction box which it had dented. Dummy might therefore have moved further. Left shoulder and left hip looser	Not worn
		Crouching	Facing	6¾	-	Lying on left side, left arm underneath. Overall scorched and torn down thighs and arms. Motion not impeded by small bush beside head. Left hip looser	6¾
		Crouching	Sideways Left Side On	6½	1	Lying on left side. Left sleeve and left trouser torn and charred. Left shoulder and left knee stiffer	14½
		Prone	Facing	Nil	-	Helmet still on, with paint scorched in front. Position unchanged. Overall slightly scorched at wrist. Left and right shoulders looser	-
		Prone	Sideways Left Side On	Head 1½ Feet ¾	-	Lying on face. Left arm back and crumpled. Overall left sleeve torn and charred. Left shoulder and left knee looser	
P14	2650	Standing	Facing	14¾	¾	Lying on back. Right arm bent under. Right sleeve charred and torn. Left elbow looser	Not worn
		Standing	Sideways Left Side On	9	-	Lying on face. Feet caught in cable, which may have restricted further movement. Overall torn and charred down leftside. Left hip looser	Not worn
		Crouching	Facing	¼	2	Overall caught on scaffold support, dummy falling sideways. Axial backward movement probably not substantially affected by this. Left shoulder and right knee stiffer, left knee looser. Helmet still on head	-
		Crouching	Sideways Left Side On	4¾	-	Lying on right side. Overall left sleeve charred and torn. Left hip looser	80½
		Prone	Facing	-	-	Right arm blown back. Helmet on ground in front of head. Left hip looser	-
		Prone	Sideways Left Side On	1½	-	Lying on face. Arms above head. No change in stiffness of joints	25½
P15	3100	Standing	Facing	10½	1¾	Lying on back. Left arm doubled back. Joint in back broken. Left shoulder looser. Left hip stiffer	Not worn
		Standing	Sideways Left Side On	6¾	1½	Lying on back, bent to left from hips. Left sleeve charred. Right hip looser	Not worn
		Crouching	Facing	-	¼	Slightly displaced to left. Right arm bent back to hips. Right shoulder looser. Helmet dropped off just in front	-

APPENDIX A (Cont.)

Target No.	Range, ft	Dummy		Displacement		Observations	Displacement of Helmet, ft
		Position	Orientation	Axial, ft	Laterally, ft		
P15 (cont.)		Crouching	Sideways Left Side On	3	1	Lying on right side. Left sleeve charred. Right shoulder and right hip looser	66
P11	3900	Standing	Facing	6½	-	Lying on back. Both elbows doubled back. Both shoulders stiffer. Left hip looser	Not worn
		Standing	Sideways Left Side On	4¾	2¼	Lying on back. Left arm doubled back. Right arm out sideways. Left knee stiffer	-
		Crouching	Facing	-	½	Slightly displaced to left. Position otherwise unchanged. Helmet still on head but had slipped forward. No change in joint	-
		Crouching	Sideways Left Side On	-	-	Position unchanged. No change in joints	15½

A2. Round 3

Target No.	Range, ft	Dummy		Displacement, ft	Observations	Displacement of Helmet, ft
		Position	Orientation			
501	1860	Prone	Facing	5	Dummy was lying 10 ft behind a small ridge about 9 in. high. Badly burnt on back, arms and legs. Tunic removed by blast or heat	-
		Prone	Sideways Left Side On	67	Originally sited as above. Both forearms broken off. Entire left side lacerated	-
502	2110	Prone	Facing	70	Body broken in two. Head and chest travelled 77 ft, legs and stomach 67 ft. All flesh off chest and back	80
		Prone	Sideways Left Side On	280	Body broken up. Torso found with chest lacerated with small stones up to 2 in. diameter embedded. Both forearms missing	-
503	2330	Prone	Facing	79	Found on back with right leg missing. Left shoulder lacerated, left arm flesh torn off	-
			Sideways Left Side On	170	Badly battered. Right leg off. Flesh stripped from left side of the body. Chest and stomach lacerated, with small stones embedded	-

APPENDIX B

Results of Exposing Dummies in Champ Cars - Round 3

Target No.	Range, ft	Champ		Dummy		Observations	Displacement of Helmet, ft
		Orientation	Displacement, ft	Position	Displacement, ft		
501	1860	Facing	87	Passenger	87	Head and chest found 12 ft in front of vehicle. Legs and belly still in vehicle which was lying on its right side	-
				Driver	97	Lying 10 ft beyond car. Left leg missing. Right shoulder almost severed. Right forearm flesh badly torn	-
502	2110	Facing	115	Passenger	115	Lying with back on ground and feet in driver's seat of vehicle lying on right side. Chest and shoulders flesh torn	-
				Driver	115	Lying on face on ground by car. Chest, shoulder and left forearm lacerated. Small stones embedded in chest	-
503	2380	Facing	66	Passenger	88	Lying on side 22 ft behind car. Right leg joint bent. Chest, left arm and leg lacerated	-
				Driver	66	Underneath car completely burnt	-
503S	2380	Sideways	250	Passenger	515	Body broken up. Only head and chest identified. Car had broken into three parts. Chassis travelled 210 ft, Engine 252 ft and Body 295 ft	275
				Driver	534	Body broken up. Only head identified	-
504	2630	Facing	28	Passenger	28	Body burnt in car fire. Remained in seat	230
				Driver	28	Body burnt in car fire. Remained in seat	-
505	2825	Sideways	113	Passenger	65	Body burnt	-
				Driver	74	Lying on right side. Left leg lacerated and left thigh scorched	-
506	2920	Facing	30	Passenger	30	Still in car. Tunic stripped off. Left arm flesh torn, but otherwise undamaged	300
				Driver	30	Still in car. Tunic stripped off. Spandoplast still in position but had shrivelled from heat. Small fragments of windscreen glass embedded in plastic but had not penetrated into dummy's chest	-
507	3110	Facing	9	Passenger	9	Dummy still in seat. Face blackened. Spandoplast missing. Piece of wood 1 in. long 1/4 in. diameter had penetrated chest 0.3 in.	390
				Driver	9	Dummy still in seat. Spandoplast still in position but had shrivelled from heat. Small fragments of windscreen glass were embedded in it. Left elbow was looser	400

APPENDIX C

Damage to Daimler Scout Cars - Sideways to Ground Zero - Round 2

Target No.	Range, ft	Movement	Instrumentation C = Car D = Dummy	Site Conditions	Damage	Damage Category
P1	1730	Car turned onto side	CD	Soft sand	Car turned onto side. Bins open and crushed in by blast. Paint on Ground Zero side scorched. Tyres slightly charred (see Figures 42 and 43)	L3
P3	2200	Final position 4 in. further away from Ground Zero. Probably moved a further 3 in.	D	Sand - fairly firm	Paint scorched on Ground Zero side. Tyres slightly scorched. Rear bin near Ground Zero open and slightly dished	L1
P2	2530	3 in.	D	Hard standing	Front bin dished with lid open. Paint scorched on Ground Zero side	L1
P4	2650	Nil	CD	Hard standing	Rear bins lids open. Paint scorched on Ground Zero side	L1

Basic Blast and Thermal Data - Rounds 2 and 3

APPENDIX D

Distance, ft	No.	Target	Peak Static Overpressure, p.s.i.	Dynamic Pressure (Calculated), p.s.i.	Duration of Positive Phase, sec	Time of Arrival of Shock, sec	Integrated Heat Dose, cal cm ⁻²

Round 2 - Yield About 5 kilotons

1460	P18	Dummies	15.3	5.0	0.38	No Record	62
1590	P19	Dummies	13.0	3.7	0.40	0.61	51
1730	P1	Scout Car	11.3	2.8	0.42	0.70	43.5
1750	P26	Missile Trap	11.0	2.7	0.42	0.72	43
1840	P10	Dummies	9.8	2.2	0.44	0.78	38.5
2000	P16	Dummies	8.3	1.6	0.46	0.90	33
2200	P12) P3)	Dummies Scout Car	7.0	1.1	0.48	1.05	27
2360	P23	Missile Traps	6.2	0.9	0.50	1.17	23.5
2390	P13	Dummies	6.1	0.9	0.50	1.20	22.5
2530	P2	Scout Car	5.4	0.7	0.50	1.30	20
2650	P4 P14	Scout Car Dummies	5.1	0.6	0.53	1.39	18.7
3066	P21	Missile Traps	4.1	0.4	0.56	1.72	14.2
3110	P15	Dummies	4.0	0.4	0.57	1.76	13.7
3900	P11	Dummies	2.8	0.2	0.63	2.41	8.6

Round 3 - Yield About 25 kilotons

1860	501	Dummies in Champs and in open	12.0	11.5	0.61	0.63	310
2110	502		12.0	7.9	0.65	0.76	230
2380	503		12.0	5.1	0.68	0.92	180
2630	504	Dummies in Champs	12.0	3.6	0.71	1.09	145
2825	505		11.0	2.9	0.73	1.22	125
2920	506		10.5	2.4	0.75	1.28	117
3110	507		10.0	2.0	0.76	1.42	103

APPENDIX E

Meteorological Conditions at the Time of Firing - Rounds 1, 2 and 3

Round No.	Date Fired	Time Fired, hours (local)	Barometric Pressure, mB	Air Temperature, °F	Relative Humidity, %	Surface Wind	
						Direction	Speed, knots
1	14.9.58	1435	1001.3	63.5	28	220°	22
2	25.9.58	1000	1003.7	55	68	Variable	2
3	9.10.58	1615	988.6	91.5	23	215°	5










References

1. J. H. Butterfield, Maj. E. G. Hardy, RAMC and E. R. Drake Seager: "Operation Buffalo: Target Response Tests: Biology Group. Part 3(a). The Effects of Blast on Dummy Men Exposed in the Open". AWRE Report No. T2/59.
2. Lt. Col. J. N. W. Hearn, RA: "Operation Buffalo: Interim Report: Target Response Ordnance Group". AWRE Report No. T25/57.









VEC

Plotting Data for Figure 1

Target No.	Presented Area × Peak Dynamic Pressure × Duration of Impulse, lb/sec	Displacement, ft	Symbol
P18	409	6	△
P18	1360	11	△
P19	318	6	△
P19	1060	28	△
P10	683	14	△
P12	388	4	△
P12	310	4	○
P12	387	7	⊖
P13	348	2	△
P13	248	7	⊙
P13	310	8	⊖
P13	310	8 - 3* = 5	◻
P13	620	16 - 3* = 13	◻
P14	233	1	△
P14	233	5	⊖
P14	233	9 - 3* = 6	◻
P14	466	15 - 3* = 12	◻
P15	156	3 - 1* = 2	⊖
P15	156	6 - 3* = 3	◻

Target No.	Presented Area × Peak Dynamic Pressure × Duration of Impulse, lb/sec	Displacement, ft	Symbol
P15	312	11 - 3* = 8	
P11	86	5 - 3* = 2	
P11	173	6 - 3* = 3	
501	1510	5	
501	5050	67	
502	1110	70	
502	3690	280	
503	750	79	
503	2500	170	

KEY

-  Prone Facing Round 2
-  Prone Sideways Round 2
-  Crouching Facing Round 2
-  Crouching Sideways Round 2
-  Standing Facing Round 2
-  Standing Sideways Round 2
-  Prone Facing Round 3
-  Prone Sideways Round 3

*Correction for Toppling

6 Dummies moved less than 1 ft and are not included in this Table
(See Appendix A)

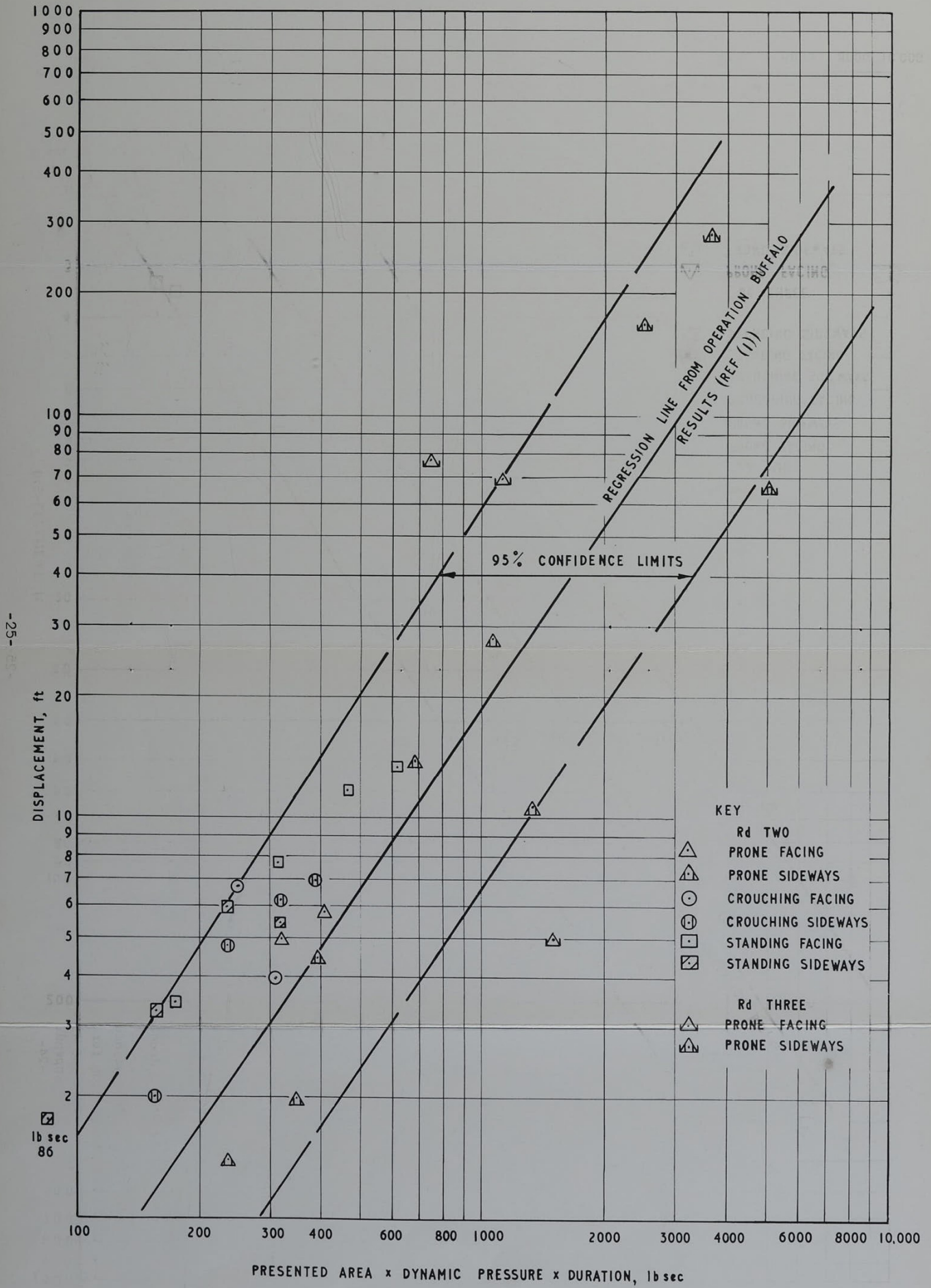
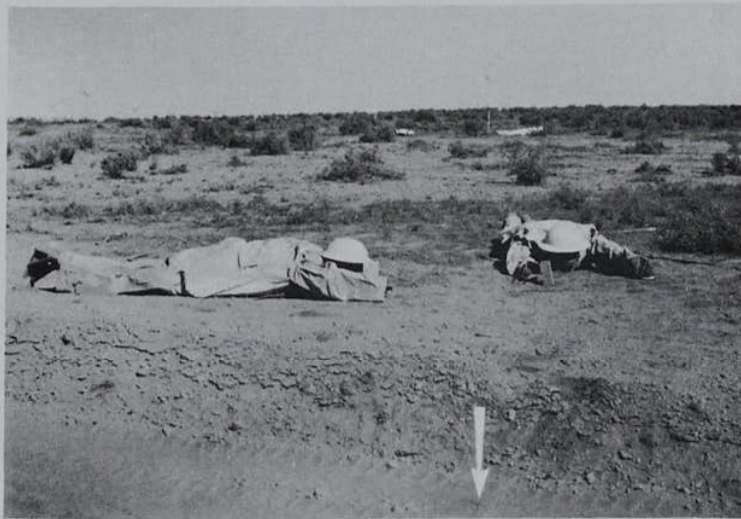


FIGURE 1



G.Z.

FIGURE 2. ROUND 2. DUMMIES AT 1460 ft BEFORE FIRING. NOTE POSITION JUST BEHIND TRACK



G.Z

FIGURE 3. ROUND 2. PRONE SIDWAYS DUMMY AT 1460 ft OVERALL TORN AND CHARRED



G.Z.

FIGURE 4. ROUND 2. PRONE FACING DUMMY AT 1460 ft
NOTE OVERALL ALMOST OFF, BUT FLESH ONLY
SLIGHTLY SCORCHED



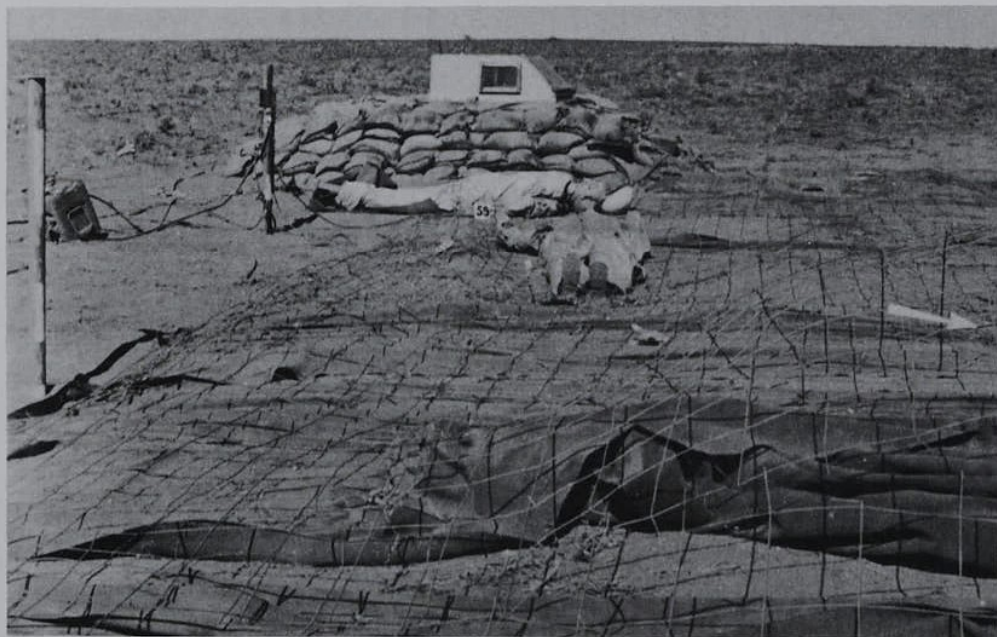
G.Z.

FIGURE 5. ROUND 2. PRONE FACING DUMMY AT 1840 ft
NOTE HELMET WHICH REMAINED ON HEAD
DURING POSITIVE PHASE OF BLAST

G.Z.



FIGURE 6. ROUND 2. PRONE DUMMIES AT 2000 ft BEFORE FIRING.
NOTE SEALED SURFACE OF WIRE MESH ON TARPAULINS
SECURED BY STAKES



G.Z.

FIGURE 7. ROUND 2. PRONE DUMMIES AT 2000 ft AFTER FIRING.
NOTE WIRE MESH HAS IMPEDED MOTION OF PRONE
SIDWAYS DUMMY

G.Z.

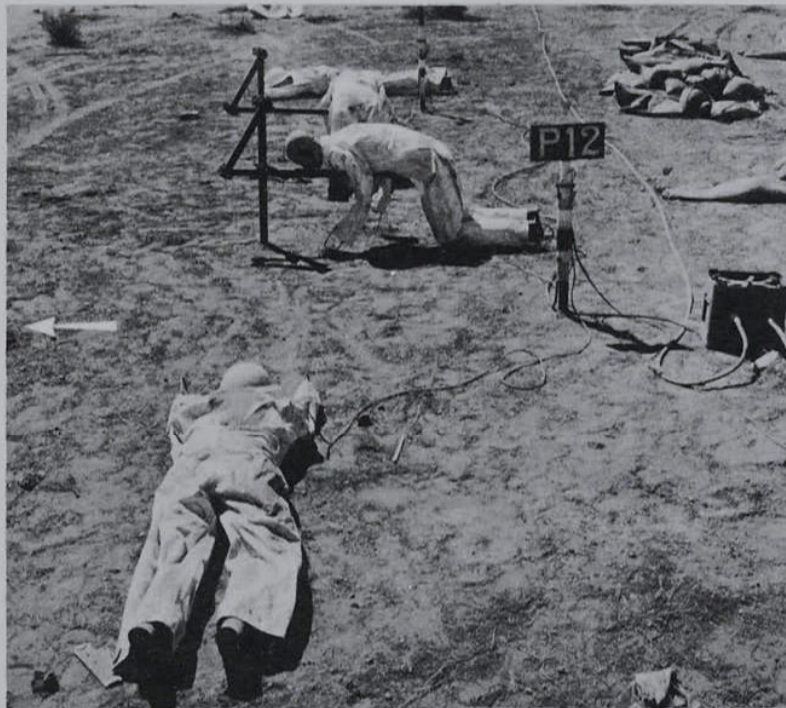


FIGURE 8. ROUND 2. PRONE AND CROUCHING DUMMIES AT 2200 ft BEFORE FIRING. NOTE INSTRUMENTATION LIABLE TO CATCH IN FEET. SANDBAGS WERE REMOVED BEFORE FIRING



FIGURE 9. ROUND 2. DUMMIES AT 2200 ft. NOTE WHITE NAILS IN FRONT OF PRONE FACING DUMMY USED AS A REFERENCE MARK

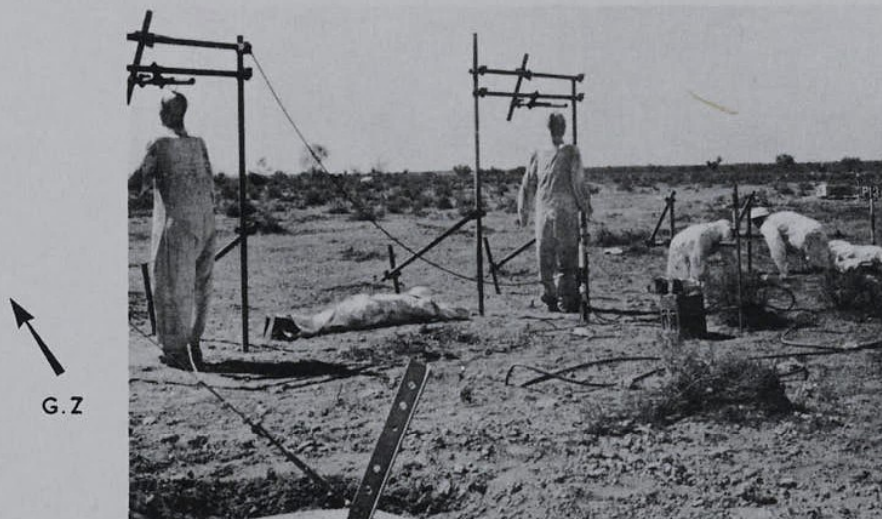


FIGURE 10. ROUND 2. DUMMIES AT 2390 ft BEFORE FIRING.
NOTE SCAFFOLDING USED TO SUPPORT DUMMIES



FIGURE 11. ROUND 2. DUMMIES AT 2390 ft AFTER FIRING.
NOTE CAMERA TOWER IN BACKGROUND, AND
LACK OF MOVEMENT OF THE PRONE FACING DUMMY



FIGURE 12. ROUND 2. DUMMIES AT 3100 ft AFTER FIRING. NOTE
CROUCHING FACING DUMMY HAS REMAINED ON THE
SUPPORT AND HELMET HAS DROPPED OFF AFTER
POSITIVE PHASE



FIGURE 13. ROUND 3. CHAMP AT 1860 ft. NOTE LOWER HALF
OF DUMMY DRIVER IN WRECKAGE

↓
G.Z



FIGURE 14. ROUND 3. PASSENGER OF CHAMP AT 1860 ft.
NOTE UPPER PART OF DUMMY DRIVER IN
FRONT OF CHAMP



G.Z.

FIGURE 15. ROUND 3. CHAMP AT 2110 ft SHOWING
DRIVER AND PASSENGER THROWN OUT
OF VEHICLE



GZ

FIGURE 16. ROUND 3. VIEW OF FRONT 4 CHAMPS AFTER FIRING
WITH SCATTERED DEBRIS



GZ

FIGURE 17. ROUND 3 . CHAMP AT 2630 ft DUMMIES BURNT
IN SITU BY PETROL FIRE



FIGURE 18. ROUND 3. DUMMY PASSENGER FROM CHAMP
SIDEWAYS TO BLAST AT 2825 ft BURNT OUT
AND WITH ONE LEG MISSING

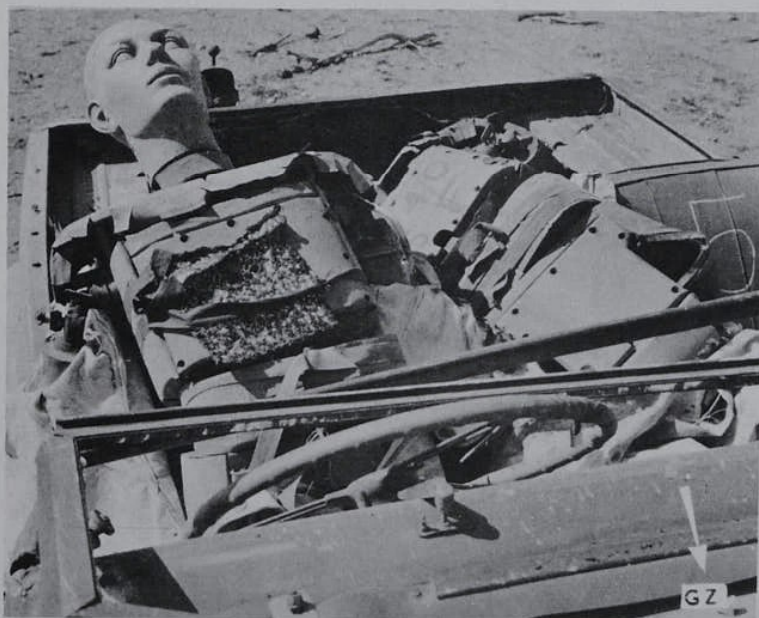


FIGURE 19. ROUND 3. CHAMP AT 2920 ft NOTE CONDITION
OF SPANDOPLAST ON DRIVERS CHEST WHICH HAS
SHRIVELLED WITH HEAT

GZ



FIGURE 20. ROUND 2. SCOUT CAR AT 1730 ft BEFORE FIRING.
THIS ALSO GIVES GOOD VIEW OF TERRAIN IN THE
TARGET AREA

GZ



FIGURE 21. ROUND 2. SCOUT CAR AT 1730 ft AFTER FIRING.
NO APPARENT DAMAGE TO DUMMY OR SCOUT CAR
WHICH SIMPLY TURNED OVER ONTO ITS SIDE



G.Z.

FIGURE 22. ROUND 2. SCOUT CAR AT 2200 ft AFTER
FIRING. NOTE SOIL DISPLACED BY WHEEL
WHEN CAR MOVED SIDWAYS 4 INCHES



FIGURE 23. DUMMY IN TRENCH AT 2390 ft BEFORE FIRING

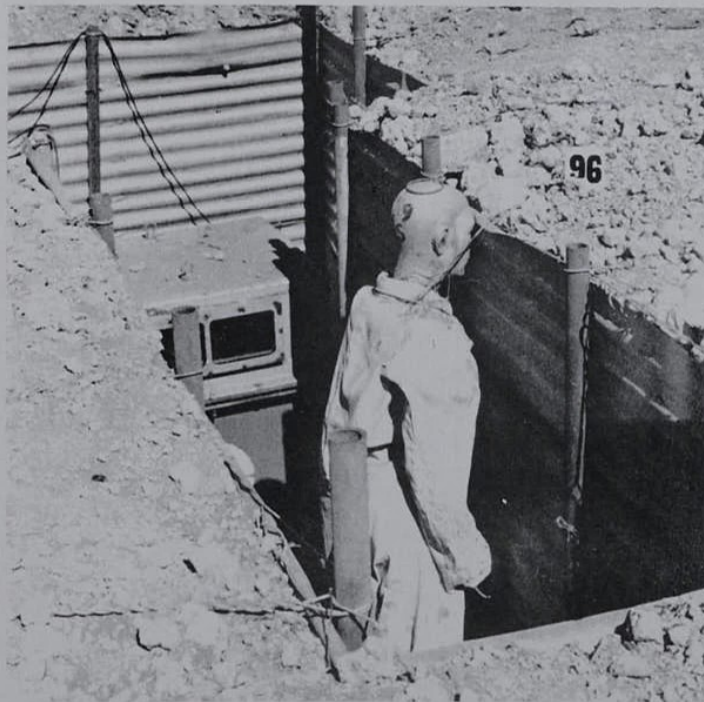


FIGURE 24. DUMMY IN TRENCH AT 2390 ft AFTER FIRING

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